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Pterion has gathered considerable attention in primate morphology, because of its high power characterizing New World Monkey (e.g. Rosenberger, 1977). In platyrrhine primates, pterion is composed of frontal, sphenoidal, parietal and zygomatic bones, while in catarrhines, composed of frontal, sphenoidal, parietal and temporal bones. Furthermore, platyrrhine pterion can be classified into two types according to its sutural pattern; spheno-frontal articulation type (SF type) pterion and parieto-zygomatic articulation type (PZ type) pterion. In the extensive study on primate pterion by Ashley-Montagu (1933), all callitrichids and 83.8% of cebids have PZ type pterions, while only the small portion (14.8%) of cebids has SF type pterion. But SF type pterion occurred in about 60% of *Alouatta*, highest incidence in Cebidae, to say nothing of Ceboidea. The purpose of this study is to expain the high incidence of SF type pterion in *Alouatta*, analyzing the relation between incidences of SF type pterion and cranial mid-sagittal measurements of subsamples set up on the ground of age, sex and specific distinctions.

MATERIALS AND METHODS

Alouatta crania analyzed in this study came from the collections of Instituto de Ciencias Naturales de la Universidad Nacional, Colombia (40), Instituto de Desarollo de los Recursos Naturales Renovables, Colombia (22), and Field Museum of Natural History, U.S.A. (34). Collection numbers of crania are included in appendix. Of total 96 crania, 80 are of *A. seniculus* and 16 are of *A. beizebul.* Age and sex composition is shown in Table 1. Five age classes are classified according mainly to dental eruption; class I only with deciduous dention, class II with erupting one to fully erupted four first molar(s), class III with more than five molars but without last third molar fully erupted, class IV with fully erupted twelve molars and open spheno-occipital synchondrosis, and class V with full dentition and oblitelated spheno-occipital synchondrosis.

Pterions are classified into SF type and PZ type pterion on both left and right sides of skulls. In SF type pterion, sphenoidal bone articulates with frontal bone and separates parietal from zygomatic bone, while in PZ type pterion, articulation between parietal and zygomatic bones separates sphenoidal from frontal bone. Point type pterion, in which four bones meet at a point, is absent in the present study. Frequencies of SF type pterion are calculated, based on side not on skull. To represent mid-sagittal section of skull, distances are measured between every two points of the following 4 landmarks except the distance between prostion and inion; nasion, inion, basion and prostion. In this study, inion means the tip of external occipital prominence.

As for statistical significance, chi-square test or Fisther's exact probability is used for frequencies, and t-test for measurements.

Table 1. Age and sex composition of crania studied.

Age	*Alouatta seniculus* Male	Female	?	Total	*Alouatta belzebul* Male	Female	?	Total
Class I	1	1	1	3	0	0	0	0
Class II	4	1	2	7	0	0	0	0
Class III	2	1	2	5	4	0	0	4
Class IV	12	4	0	16	3	3	0	6
Class V	20	29	0	49	2	4	0	6
Total	39	36	5	80	9	7	0	16

RESULTS

The incidences of SF type pterion are presented in Table 2. The incidence of SF type pterion is higher in *A. seniculus* (77.2%) than in *A. belzebul* (59.1%). In *A. seniculus*, SF type pterions occur more frequently in male (85.4%) than in female (71.4%). But these specific and sex differences of frequencies of SF type pterions are not significant at 5% level, partly due to small sample size caused by early sutural obliteration in *Alouatta*. The occurrence pattern of SF type pterion in *A. seniculus* shows neither age-progressive nor age-regressive tendency.

Table 3 presents the means and standard deviations of five cranial mid-sagittal measurements. Mean values are used to reconstruct tetragons with one diagonal (nasion-basion), which represent schematically cranial mid-sagittal sections. Fig. 1 illustrates cranial mid-sagittal growth in male *A. seniculus*, using above-mentioned tetragons. In the lower triangles of this schema the greatest post-natal change takes place in prostion-basion length, reflecting disproportional growth of subbasally lying vocal apparatus including basihyal (Biegert, 1963; Watanabe, 1982). Fig. 2 shows following three schematic comparisons between

Table 2. Side incidence of SF type pterion.

	Alouatta seniculus								*Alouatta belzebul*					
	Male		Female		Sex-unknown		Total		Male		Female		Total	
Age		%		%		%		%		%		%		%
Class I	2/2	100.0	2/2	100.0	2/2	100.0	6/6	100.0						
Class II	8/8	100.0	1/2	50.0	1/4	25.0	10/14	71.4						
Class III	4/4	100.0	0/2	0.0	2/4	50.0	6/10	60.0	6/8	75.0			6/8	75.0
Class IV	19/24	79.2	6/7	85.7			25/31	80.6	3/6	50.0	2/2	100.0	5/8	62.5
Class V	8/10	80.0	6/8	75.0			14/18	77.8	0/2	0.0	2/4	50.0	2/6	33.3
Total	41/48	85.4	15/21	71.4	5/10	50.0	61/79	77.2	9/16	56.3	4/6	66.7	13/22	59.1

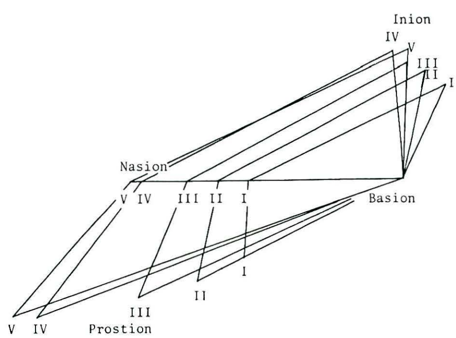

Fig. 1. Cranial mid-sagittal growth in male *Alouatta seniculus*.

Table 3. Cranial mid-sagittal measurements.

Measurement	Species and sex	Age class V			Age class IV			Age class III			Age class II			Age class I		
		N	Mean	S. D.	N	Mean	S. D.	N	Mean	S. D.	N	Mean	S. D.	N	Mean	S.D.
Nasion-inion	sen. M	20	81.35	7.07	12	75.17	6.31	2	66.00	7.07	4	61.75	4.65	1	58	
	sen. F	29	71.17	4.16	4	67.75	1.50	1	64		0			1	55	
	bel. M	2	75.50	0.71	3	80.33	4.51	4	70.00	5.23	0			0		
	bel. F	4	69.25	1.26	3	71.33	2.08	0			0			0		
Nasion-prostion	sen. M	20	46.40	3.69	12	44.83	4.45	2	33.00	0.00	4	26.50	2.52	1	20	
	sen. F	29	37.86	2.53	4	34.25	1.89	1	32		1	29		1	20	
	bel. M	2	47.50	2.12	3	51.00	0.00	4	41.00	3.16	0			0		
	bel. F	4	39.00	2.71	3	39.33	1.53	0			0			0		
Nasion-basion	sen. M	20	72.70	3.93	12	69.42	5.21	2	57.50	0.71	4	49.25	2.06	1	42	
	sen. F	29	61.93	3.09	4	59.50	1.73	1	55		0			1	43	
	bel. M	2	70.00	2.83	3	74.33	6.66	4	62.75	2.99	0			0		
	bel. F	4	61.50	0.58	3	61.67	2.31	0			0			0		
Basion-prostion	sen. M	20	109.20	6.93	12	103.67	9.75	2	77.50	2.12	4	61.75	3.77	1	48	
	sen. F	29	88.69	4.80	4	83.25	5.38	1	77		0			1	50	
	bel. M	2	103.50	4.95	3	112.00	9.64	4	90.50	5.80	0			0		
	bel. F	4	86.25	2.87	3	89.67	0.57	0			0			0		
Basion-inion	sen. M	20	33.30	1.59	12	33.00	1.21	2	30.00	2.83	4	28.25	1.50	1	27	
	sen. F	29	30.52	2.01	4	30.75	0.50	1	29		0			1	24	
	bel. M	2	30.50	0.71	3	33.33	0.58	4	30.50	1.29	0			0		
	bel. F	4	29.00	0.81	3	29.67	2.08	0			0			0		

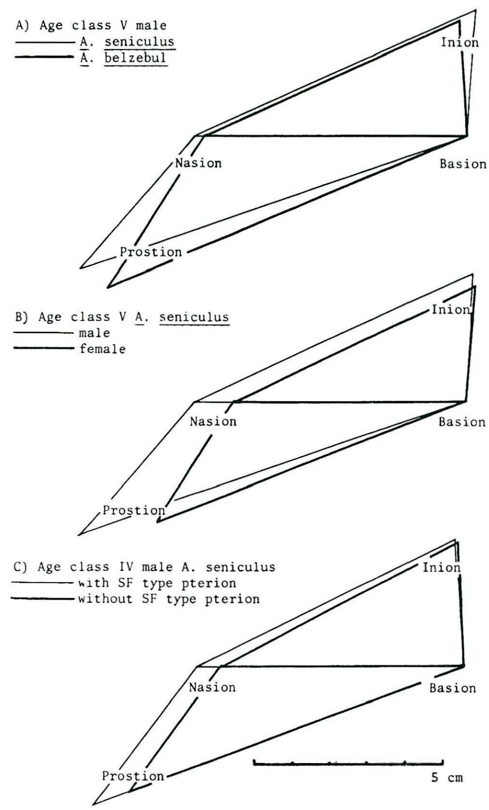

Fig. 2. Schematic comparisons of cranial mid-sagittal section.

cranial mid-sagittal sections of subsamples with different frequencies of SF type pterion; A) age class V male subsamlpe of *A. seniculus* versus that of *A. belzebul*, B) in *A. seniculus* sample, subsample of age class V males versus that of females and C) in the sample of age class IV males of *A. seniculus*, nine males with SF type pterion versus three males without SF type pterion. In all three comparisons, subsamples with higher SF type pterion frequencies have longer prostion-basion lengths. To a lesser extent than prostion-basion length, nasion-basion lengths are also longer in subsamples with higher SF type pterion frequencies than in those with lower frequencies of SF type pterion.

DISCUSSION

On the relation between non-metric and metric traits, a profound controversy exists. Berry and Berry (1967, 1972) and Kellock and Parsons (1970) assumed complete independence of non-metric traits from metric ones. On the other hand, Corruccini (1976) and Cheverud et al. (1979) insist on associations between non-metric and metric traits. The result of this study suggests that moderate degree of correlation exists in *Alouatta* between occurrence of SF type pterion (non-metric trait) and antero-posterior elongation of skull which is documented by mid-sagittal measurements. Age factor can not explain this correlation, for the occurrence pattern of SF type pterions does not show age-dependent increase. A possible explanation of this correlation is causal relationship between two correlates. Namely, occurrence of SF type pterion is a cause of antero-posterior elongation of skull, or vice versa. Considering the importance of ontogenetic priority, it seems more likely that pterionic configulation is the cause of cranial elongation, for SF type pterion occurs early in age class I individuals while cranial elongation develops later in growth. But setting value on function, opposite view of causal relation seems more likely, because no function can be assumed for pterionic configulation. It is difficult to choose one between these two possibilities. Tentatively, following interpretation is assumed.

On the correlations between non-metric and metric traits, Cheverud et al. (1979) state that "The cause of these correlations may lie in the common effects that growth and development of the soft tissue and functional spaces of the cranium exert on both metric and non-metric." In the case of *Alouatta*, both high frequency of SF type pterion and cranial antero-posterior elongation may be influenced by the specialized enlargement of the vocal apparatus.

Whatever the cause of the correlation between occurrence of SF type pterion and cranial antero-posterior elongation in *Alouatta* may be, this correlation has practical implication that pterionic variation can not be used as a independent character from general or local measurements of skull in taxonomic study of *Alouatta*.

CONCLUSIONS

The incidence of SF type pterion in *Alouatta* is higher in *A. seniculus* (77.2%) than in *A. belzebul* (59.1%), and in *A. seniculus*, higher in males (85.4%) than in females (71.4%), and does not show age-progressive pattern. Comparisons between the frequencies of SF type pterion and cranial mid-sagittal measurements shows moderate degree of correlation between occurrence of SF type pterion and antero-posterior elongation of skull. This correlation has practical implication that pterionic variation can not be used as a independent character from craniometric variation in taxonomic study of *Alouatta*.

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APPENDIX: Collection numbers of crania studied.

Alouatta seniculus

Im: ICN-225; If: ICN-2082; I?: IND-M-0741; IIm: IND-M-0735, IND-M-2820, IND-M-0771, FM-93265; IIf: ICN-144; II?: IND-M-0738, IND-M-0755; IIIm: IND-M-2826, ICN-1390; IIIf: ICN-1387; III?: IND-M-0747, IND-M-0754,; IVm: FM-93248, FM-95493, FM-95348, ICM-1666, INC-6890, ICN-1379, FM-41498, IND-M-2711, IND-M-0820, ICN-1679; ICN-103, ICN-1389; IVf: ICN-1384, ICN-714, ICN-1386, IND-M-0478; Vm: ICN-1380, IND-M-1528, FM-17759, ICN-1378, FM-95495, ICN-090, ICN-334, ICN-1381, IND-M-1335, IND-M-0791, IND-M-0560, IND-M-3057, ICN-3092, ICN-1779, ICN-1678, ICN-2899, FM-93246, FM-93249, FM-64277, FM-64278; Vf: ICN-094, ICN-072, ICN-711, ICN-340, ICN-1382, ICN-071, ICN-164, ICN-089, ICN-1383, ICN-4975, ICN-1388, ICN-770, ICN-2956, ICN-1385, IND-2861, IND-M-2712, IND-M-2913, IND-M-2710, IND-M-2596, ICN-1391, ICN-1778, ICN-1677, FM-95492, FM-31095, FM-55505, FM-41499, FM-55506, FM-64279, FM-64280.

Alouatta belzebul

IIIm: FM-92087, FM-92094, FM-94932, FM-94935; IVm: FM-92091, FM-94931, FM-94934; IVf: FM-50884, FM-92088, FM-94936; Vm: FM-92090, FM-92095; Vf: FM-92089, FM-92097, FM-92097, FM-92099.

Note: I, II, III, IV and V designate age classes: m, male; f, female; ?, sex unknown; ICN, Museo de Ciencia Naturales de la Universidad Nacional, Colombia; IND or IND-M, Instituto de Desarrollo de los Recursos Naturales Renovables, Colombia; FM, Field Museum of Natural History, Chicago. U.S.A.